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SELECTED REFERENCES ON INNOVATIVE/ALTERNATIVE WASTEWATER COLLECTION SYSTEMS FOR CORPS OF ENGINEERS RECREATION AREAS

by

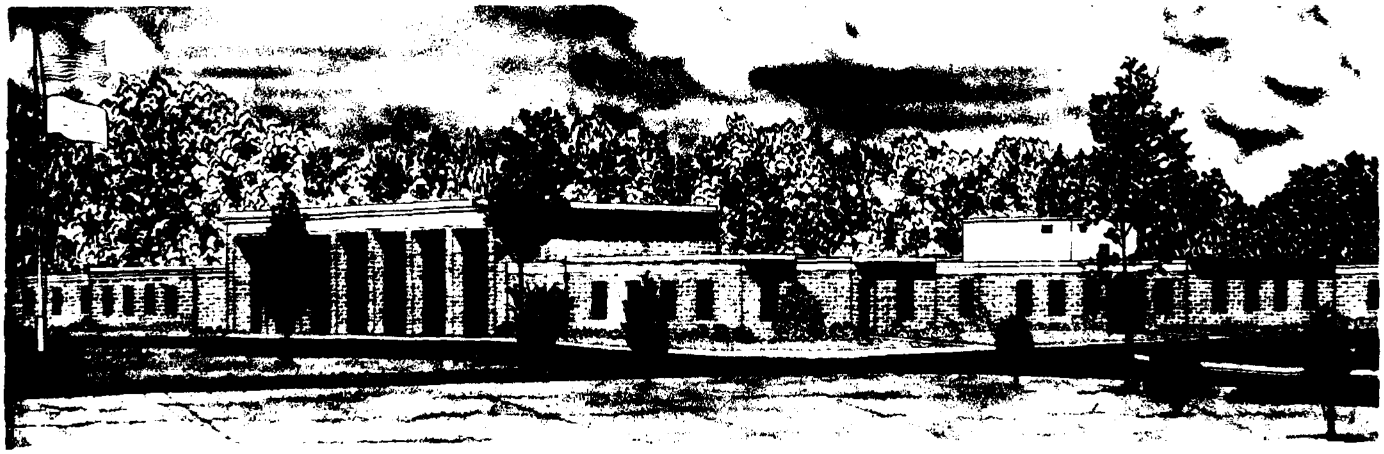
Frances M. Kelsi and M. John Cullinane, Jr.

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

January 1981

Final Report

Approved For Public Release; Distribution Unlimited



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[illegible] development of innovative/alternative wastewater collection systems [illegible] by the increase in construction cost of conventional gravity [illegible] systems. Four classifications of innovative/alternative collection [illegible] systems have received the most attention from the research [illegible] community. Systems available for application to recreation [illegible] include: pressure systems, vacuum systems, small diameter [illegible] systems, and recycle/reuse systems. Information concerning these
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20. ABSTRACT (Continued).
systems is diffuse and in many cases limited in scope. Annotations are presented for selected references on available innovative/alternative collection systems. Fifty-three references are presented for pressure systems and fourteen references are presented for vacuum systems. An additional twenty-seven references on related subject matters are also included.

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PREFACE

The study reported herein was funded by the Office, Chief of Engineers, U. S. Army, from Civil Works Appropriation 96X3121, General Investigations - Research and Development.

The study was conducted during 1980 by personnel of the Environmental Engineering Division (EED), Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksubrg, Miss.

The study was conducted by Ms. Frances M. Kelsi and Mr. M. John Cullinane, Jr. The work effort was accomplished under the direct supervision of Mr. Norman R. Francingues, Chief, Water Supply and Waste Treatment Group, and the general supervision of Mr. Andrew J. Green, Chief, EED, and Dr. John Harrison, Chief, EL. This report was prepared by Ms. Kelsi and Mr. Cullinane, EED.

Commander and Director at WES during the study and preparation of this report was COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

This report should be cited as follows:

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CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
feet per second	0.3048	metres per second
gallons per minute	3.785412	cubic decimetres per minute
gallons (U. S. liquid)	3.785412	cubic decimetres
horsepower (550 foot-pounds per second)	745.6999	watts
inches of mercury (32°F)	3386.38	pascals
kilowatt hours	3600000.0	joules
pounds (force) per square inch	6894.757	pascals

SELECTED REFERENCES ON INNOVATIVE/ALTERNATIVE WASTEWATER COLLECTION SYSTEMS FOR CORPS OF ENGINEERS RECREATION AREAS

PART I: INTRODUCTION

Background

1. The U. S. Army Corps of Engineers (CE) is responsible for designing, constructing, maintaining, and operating wastewater collection and treatment systems for its recreation areas located nationwide. The use of these areas for over 479 million visitor days in 1979 emphasizes the magnitude of this responsibility.

2. Water-based transport of waste plays a dominant role in the provision of sanitary services to CE recreation areas. Traditionally, waterborne waste carriage systems transmit waste via the force of gravity or a combination of gravity and a series of lift stations and force mains. In many cases, however, the use of conventional sewerage technology may not represent the best available technology as applied to site-specific problems. This may be particularly true for those sites developed as CE recreation areas that may have unusual topographic, geologic, or development density constraints.

3. The solution to these site-specific problems typical of CE recreation areas may require adaptation of innovative/alternative collection systems previously developed for application to the problem of collecting and transporting wastewater generated in the municipal scenario.

Purpose

4. The purpose of this study was to develop a literature base that would serve to supply information necessary to formulate research and development requirements, if any, related to application of innovative/alternative collection systems to CE recreation area requirements.

PART II: INNOVATIVE/ALTERNATIVE SYSTEMS

Background

5. The development of innovative/alternative wastewater collection systems has been spurred by the increase in construction cost of traditional gravity collection systems and a realization that the aesthetic desirability of many sites proposed for development may be inversely proportional to the technical and economic feasibility of supplying sanitary services by conventional means. Four classifications of innovative/alternative collection and transportation systems have received the most attention from both research and development and actual application. These include: pressure systems, vacuum systems, small diameter gravity systems, and recycle/reuse systems.

Pressure Systems

6. Pressure sewer systems utilize pumps and small diameter force mains to collect and transport the wastewater under positive pressure, thus eliminating the need to lay pipe to hydraulic grade lines. The development of reliable pumps capable of handling small flows, the development of plastic pipe for force mains, and the high cost of conventional gravity systems have provided the major impetus for application of pressure systems.

7. Two options are available for design of pressure systems. First, grinder pumps may be utilized to both shred and simultaneously inject the wastewater into the force main system. Second, use may be made of extended primary sedimentation (i.e. septic tanks) followed by use of conventional small pumping units to inject the wastewaters into the pressure collection system. The septic tank-pumping units system has proven to be somewhat more successful in field studies.

Vacuum Systems

8. Vacuum collection systems use a central vacuum source to

maintain a constant vacuum on the transmission main. Normally, a vacuum of from 15 to 25 in. of mercury is applied. Vacuum systems are similar to positive pressure systems in that main collection lines are small diameter plastic pipe that can be installed independent of hydraulic grade lines. Generated wastewaters are collected via the applied vacuum to a central tank, from which they are pumped by conventional means to the treatment or disposal site. The system requires a normally closed valve at each point of wastewater input. Disadvantages include a limitation on the length and head of the collection system and possible vacuum leaks rendering the system inoperable.

Small Diameter Gravity Systems

9. Small diameter gravity systems are similar in design to conventional gravity systems. Small diameter polyvinyl chloride (PVC) pipe is substituted for vitrified clay or concrete. Use of PVC piping with solvent weld or O-ring joints allows use of a lower friction factor resulting in lower minimum grade requirements and smaller pipe sizes. Operational characteristics of small diameter gravity systems are not well documented at the present time.

Recycle/Reuse Systems

10. Recycle/reuse is a general classification of systems used to reduce water consumption through either complete recycle or cascade reuse of waters. Complete reuse systems are not considered to be technically or economically feasible for recreation area use at the present time. Typical recycle system scenarios separate blackwater (waters coming into contact with human excreta) and greywater (waters used for showers, laundry, handwashing, etc.) in order to simplify treatment and disposal. The greywater may be used as water closet flushing water. In the alternative, mineral oil or some other recycle fluid has been used to convey waste materials from water closets to treatment facilities. The waste materials are removed and the oil is recycled. Recycle/reuse

systems require relatively high initial cost and subsequent high operation and maintenance costs.

Summary

11. Innovative and alternative means of wastewater collection and transmission including pressure, vacuum, small diameter gravity, and recycle/reuse systems are available for application to recreation area requirements. Although these systems tend to have higher capital, operation, and maintenance costs, they may present a technically feasible and economically attractive alternative where complex site characteristics and treatment criteria are applied on a site-specific basis. In municipal development applications, pressure and vacuum systems have been found to be more cost-effective than conventional gravity systems under harsh topographic conditions including hilly or rocky terrain and low-lying areas. Innovative and alternative wastewater collection systems should be evaluated on a life cycle cost basis for each recreation facility using waterborne waste carriage.

PART III: SELECTED REFERENCES

Annotations*

Pressure systems

1. "Advanced Development of Household Pump-Storage Grinder Unit (Task 6)," by R. P. Farrell. NTIS No. PB-186 004, 1968.

As part of the American Society of Civil Engineers (ASCE) Project on Separation of Combined Sewers, a contractor has developed and constucted the first prototype of a Pump-Storage-Grinder (PSG) unit suitable for installation in individual houses. The functions of grinding, pumping, and backflow prevention are provided in an integral assembly that can be lowered into place on a field-installed steel or concrete tank. (from BSWF)

2. "Alternatives for Small Wastewater Treatment Systems: Pressure Sewers/Vacuums Sewers," by J. Kriessl, I. A. Cooper, and J. W. Rezek. U. S. Environmental Protection Agency Technology Transfer Seminar, Report No. EPA-625/4-77-011, Oct 1977.

The U. S. Environmental Protection Agency Technology Transfer Report includes background information, descriptions, case studies, construction considerations, costs, and information on operation and maintenance of pressure and vacuum sewers. A design example for a vacuum system is presented in Appendix B. Lower capital costs and significantly shorter construction times are inherent in pressure sewer systems, as compared to conventional methods. But, pressure sewers should only be considered with properly conceived management arrangements (i.e. maintenance of grinder pump units).

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* Abbreviations used are as follows:
BSWF "1979 Bibliography of Small Wastewater Flows," by EPA Staff.
EI "Engineering Index."
ENV.I "Environment Index."
NTIS National Technical Information Service.
WRA "Water Resources Abstracts."

Vacuum sewer systems offer lower construction costs, decreased infiltration/inflow, reduced water consumption with use of vacuum toilets, and ease of installation. But, the complexity of vacuum equipment requires operating personnel to be properly trained to maintain a vacuum sewer system. Procedures to follow in the event of a breakdown in a vacuum system are also included in the report.

3. "Better Water Resources Through Sewerless Sanitation," by H. H. Lerch. Water Resources Bulletin, Vol 13, No. 2, pp. 401-407, 1977.

General discussion of alternative, onsite waste disposal systems now available or under development. Aerobic treatment units, recycling, composting, incinerating, and closed-loop toilets, as well as pressure systems, are briefly decribed. (from BSWF)

4. "Collection Alternative: The Pressure Sewer," by W. C. Bowne. Individual Onsite Wastewater Systems, Proc. of the Natl. Conference, 3rd, Ann Arbor, Mich., pp. 171-186, Nov 1976.

The paper discusses the concept of pressure sewers and the hardware required, and compares such systems with conventional sewers and onsite disposal alternatives. There is negligible infiltration and inflow associated with pressure sewers. Pressure sewers are adaptable to serving rural or semirural communities. Benefits are primarily economic, but may include better land use by enabling the developments of areas difficult to serve otherwise. 29 refs. (from EI)

5. "Control Techniques for Pressurized Sewerage Systems," ASCE Combined Sewer Separation Project, Tech. Mem. No. 11, PB-186 067, Mar 4, 1968.

Discussion of instrumentation and control of a pressurized sewer system. Use of a rubber-seated butterfly valve is recommended for the basic control element. Sensing devices upstream of the valve can be used to regulate flow. For nearly foolproof fail-safe control, all-hydraulic control systems are recommended in preference to pneumatic, hydropneumatic, or electronic systems. (from WRA)

6. "Cost-Effectiveness of On-Site and Community Sewerage Alternatives," by J. J. Troyan et al. Civil Engineering, Vol 47, No. 12, pp. 84-89, 1977.

Outlines a procedure for assessing the cost-effectiveness of wastewater treatment alternatives. Advantages, disadvantages, limitations, and cost factors for evaluating conventional gravity sewers, small diameter gravity sewers, pressure sewers, and vacuum sewers are described. (from BSWF)

7. "Cuyler Sewage Project - A Case Study," by James V. Feuss et al. Cortland County Health Department, N. Y., presented at Central New York Regional Planning and Development Board Wastewater Treatment Systems for Private Homes and Small Communities Conf., p. 223, 1978.

The process of designing a small municipal sewer system for Cuyler, N.Y., searching out available funds, creating a sewage district, and constructing the system, took six years. The Cuyler project is summarized along with the pressure sewer system that was selected. Total costs predicted $150,000, not including in-kind services. The unit cost is $4846. (from ENV.I.)

8. "Demonstrating the Feasibility of Vacuum and Pressure Sewers," by L. K. Clark and J. E. Eblen. Public Works, Vol 108, No. 4, pp. 81-84, Apr 1977.

Vacuum and pressure systems were utilized in a collection system constructed in Bend, Oreg. Specific information about the pumps used and the type and amount of excavation is presented. Depth of burial for pressure and vacuum systems is governed only by frost depth or surface loading conditions. The author gives a cost of the vacuum system as $9.75/ft. This figure is nearly twice the $5/lin ft for pressure sewers. The author mentions that "relays to signal the operation of the individual vacuum release valves have not performed satisfactorily to date and must be changed." Also, the draining of the condensate from the vacuum pumps had taken more operator time than any other item, about half an hour daily, but changes were being effected. Operator time was largely devoted to adjusting the sensor system for the vacuum valve operation and getting the signal system to report events to the vacuum station. The author offers no operation and maintenance information on pressure sewers.

9. "Design Handbook for Low Pressure Sewer Systems," Environment/One Corp., Schenectady, N.Y., 4th ed., 1973.

The Design Handbook includes a short description of pressure sewer systems and devotes most tables, graphs, and figures to various grinder pumps. Electrical diagrams are also offered. The Handbook is intended as a general guide and includes the following sections: Pump Selection and System Design, Choice of Positive Displacement Pumps, Motor Characteristics Required for a Grinder Pump, Indoor Versus Outdoor Characteristics, General Mechanical Features of Grinder Pump Equipment, Scouring During Low Flow Conditions in Low Pressure Sewer Systems, Effects and Control of Higher than Normal Pressures, Operation Following Extended Power Outage, Product Safety, and Serviceability and Reliability. Two to three pages are devoted to some of the sections. Charts and graphs are included. The author does report that, out of 8000 pumps in service as of December 1978, the mean time between service calls for grinder pump units for all causes exceeded three years. Also, when power is restored following an extended power outage, a majority of the pumps will attempt to run simultaneously (for automatic overload reset units).

10. "Design Procedure for a Rural Pressure Sewer System," by Richard L. Sanson. Public Works, pp. 86-87, Oct 1973.

Design assumptions for a small pressure sewer system in Grandview Lake, Ind., are presented. Fifty gallons per capita per day, with 3.3 persons per household, was assumed. Included is a figure showing pressure sewer-user flow relationships. The figure indicates PVC pipe sizes for minimum velocities of 2 ft/sec.

11. "Economical Residential Pressure Sewer System with No Effluent," by G. F. Hendricks and S. M. Rees. U. S. Environmental Protection Agency, Report No. EPA-600/2-75-072, PB-249 195, Dec 1975.

The report discusses the design of a pressure sewer system that was monitored for its effectiveness. Use of a land treatment system produced no effluent. The elimination of groundwater infiltration and restrictive elevation tolerances associated with a conventional gravity sewer system enabled it to be installed and to function economically. Initially, inefficient home grinder-pump units resulted in operational problems with the pressure system. Commercially manufactured grinder (home) units reduced these problems and increases in construction resulted. Numerous diagrams of various grinder-pump units are included. (from WRA)

12. "Effluent Pressure Sewer Systems," by R. E. Langford. Water Pollution Control Federation 1977 Annual Meeting, Philadelphia, Pa., 1977.

Provides detailed descriptions of effluent pressure sewer systems, including design, hardware, cost, septage disposal, operation, maintenance, and economics. Describes the advantages of effluent pressure sewer systems over gravity sewers and grinder pump systems. Identifies and describes past research and effluent pressure systems currently in operation. (from BSWF)

13. "Electric Energy Consumption of Selected Home Appliances," Data From: U. S. Government Publication, "Citizen Action Guide to Energy Conservation," U. S. Environmental Protection Agency, Report No. EPA-R2-72-091, 1972.

Annual energy used by an Environment/One grinder pump was estimated at 200 kwhr.

14. "Environmental Constraints Challenge Designers of Shoreline

Community Near Kansas City, Missouri," by G. Gray. Professional Engineer, pp. 42-44, Jun 1975.

A pressure sewer system was selected over an alternate gravity system for a community near Kansas City. The total construction and equipment bid for the pressure system was $1,030,108. An estimate for the gravity system was $2,250,000. The low pressure sewer system was constructed of SDR-26 (160 psi rated) PVC pressure pipe. Solvent welded joints were specified because of favorable experience with that system in achieving pressure-tight continuous lengths of pipe with built-in thrust takeup. However, the contractor requested, and was permitted to use, compression type gasketed joints, and added thrust blocks where necessary to resist the possibility of axial movement. Since the normal system pressure will be 35 psi or less, a static pressure test of 60 psi for two hours was specified. In those portions of the system which were laid through rock, a rock saw was used, and sand bedding was placed around the pipe to protect it from sharp edges. Otherwise clean earth backfill was used, and no unusual precautions were required.

15. "Envir-O-Pak: Water and Wastewater Equipment, Sales and Design Manual," Willow Grove, Pa.

Includes figures, charts, drawings, and specifications. Recycle and vacuum collection systems, pressure sewer systems, etc., are discussed. Innovative alternative systems are stressed. Basic wastewater data supplied.

16. "Experience With Grinding and Pumping of Sewage from Buildings," by D. H. Waller. ASCE Report TM-3, PB-185 997, 1967.

The combined sewer separation concept envisions the installation, in each building complex that is served by an existing combined sewerage system, of equipment that will grind building sewage and discharge it under pressure to a pressure sanitary sewerage system. (from BSWF)

17. "Experience with Pressure Sewerage," by Mortimer Clift. Journal of the Sanitary Engineering Division, ASCE, pp. 849-865, Oct 1968.

Experience with pressure sewerage over a three-year period at Radcliff, Ky., is discussed. Information on design, operation, and maintenance and cost comparisons is included.

18. "Final Report to the American Society of Civil Engineers on Task 7 and Task 9," NTIS Report No. PB 185992, 1967.

The scheme under investigation includes the conveyance of sewage from special grinder-storage-pump units in individual homes by means of pressure tubing. (from BSWF)

19. "Grinder Pump Maintenance Experience," Environment/One Corporation, Prepared by R. P. Farrell, Jun 1978. Also "Grinder Pump System Design Flow Chart," courtesy of Environment/One Corp. Water and Sewage Works, Ref. Issue, New York, N. Y. p. R240, 1978.

Environment/One Corp. maintenance experience with grinder pumps is summarized (from 1973-June 1978):

Project	No. Units Installed	Operating Time in Months	Service Calls	MTBSC*
Country Knolls South, New York	355	13,224	391	2.8 years
Weatherby Lake, Missouri	350	7,124	196	3.0 years
Lake Mohawk, Ohio	240	6,602	181	3.0 years

* The mean time between service calls (MTBSC) calculated as follows:

$$\frac{\text{Number of Units Installed} \times \text{Number of Days Since Installed}}{\text{Number of Service Calls} \times \text{Days in a Year}} = \text{MTBSC}$$

The grinder pump system design flowchart is a plot of the recommended design flow versus number of connections.

20. "Grinder Pumps and Pressure Sewers," by G. Curley, Jr. New England Water Pollution Control Association Journal, pp. 56-60, Apr 1978.

The paper discusses grinder pumps. Small grinder pumps may be of positive displacements or the centrifugal variety. Positive displacement pumps, which are generally smaller, display operational problems including the inability of the pumps to run dry, single-shaft seals lubricated only by the pumped liquid, and operating problems at shut-off with rotor-stator damage. The helical rotor-type pumps, at 10-gpm capacity, are offered primarily for individual homes, but may be used in a packaged duplex arrangement for small lift stations. The 2- to 5-hp centrifugal grinders lend themselves to individual homes as well as multi-unit lift stations with flows less than 150 gpm. The application of such pumps to high and low pressure sewer systems is discussed. (from NTIS)

21. "Highlights of Pressure Sewer System at Weatherby Lake, Missouri," Environment/One Corporation, Schenectady, N. Y.

The pressure sewer system which was constructed in 1974 and 1975 consists of 42,000 lin ft of pressure mains ranging from 2 to 6 in. All material was PVC SDR-26. There are no manholes. Each individual grinder pump has a check valve inside its tank and another in the 1-1/4-in. house pressure lateral. A workshop in the city hall has spare parts, cores, and fixtures needed for repairs and retests. An occasional motor rewind must be done outside. An average service call takes 45 min in the summer, and 1-1/2 hr in the winter. One section of the pipe froze, but this section was buried at 15 in., not the specified 36-in. depth. A serious odor complaint was solved by using 10 ppm of hydrogen peroxide fed into the pressure main from a lift station wet well.

22. "Hydraulics of a Pressurized Sewerage System and Use of Centrifugal Pumps," by L. S. Tucker. ASCE Combined Sewer Separation Project, Tech. Mem. No. 6, Nov 1967.

Hydraulic gradients for high and low sewage flows and the use of pressure control devices for service zones and interceptors applicable to pressure sewers are illustrated and discussed. A pressure control assembly would be needed immediately upstream and a surge control valve would be needed immediately downstream of a lift station. For steep drainage areas, pressure control assemblies would be needed to limit maximum pressures. Centrifugal pump characteristics are discussed and information on 32 classes of sewage and solids handling pumps is tabulated. Characteristics for centrifugal pumps capable of pumping sewage are such that maximum reasonable limits on discharge rates would be greatly exceeded if variations in total dynamic head were allowed to equal curb pressure variations that are expected in some parts of a pressure sewer system. Ordinary use of centrifugal pumps in these cases should be avoided. A possible modification of building pumping systems with a valve controlled to maintain a constant discharge pressure is discussed, together with the use of variable speed drivers. (from WRA)

23. "The Impact of Pressure Sewers on the Nation's Water Resources," by D. R. Glenn and J. G. Federico. Water Resources Bulletin, Vol 7, No. 5, pp. 1081-1092, 1971.

Pressure sewer systems are compared with conventional gravity sewer systems. The benefits of pressure sewers are cited. Itemized cost comparisons are presented for pressure and gravity sewers for a hypothetical community's sewer system. (from BSWF)

24. "Less Costly Wastewater Treatment Systems for Small Communities," U. S. Environmental Protection Agency, National Conference at Reston, Va., April 12, 13, 14, 1977. NTIS Report No. PB 293 2547AS, Report No. EPA-6019-79-010, pp. 45-53, 1977.

Pressure sewers and a case study from Glide, Oreg., are discussed. It was noted that grinder pumps are more costly than effluent pumps and quite often the entire installation is more expensive than an effluent pumping system. A pressure sewer system was chosen over conventional systems mainly on cost-effectiveness. No maintenance information was provided.

25. "Long-Term Operation of Wastewater Observation Stations (Task 2)," by R. Paul Farrell. ASCE Combined Sewer Separation, Apr 24, 1968.

Observations for seven months of household wastewater stations. Two *garbage grinders were a source* of difficulty. The 3/4-in. check valve regularly trapped fibrous or stringy materials. Results and information are reported. (from WRA)

26. "Low Pressure Sewer System with Grinder Pump Provides Wastewater Collection Versatility," by Environment/One Corporation Water and Sewage Works, Schenectady, N. Y., pp. 58-61, Nov 1973.

The low pressure sewer system has several basic premises that cannot be violated: the combination of static and friction head loss must be accurately evaluated to achieve proper pipe sizing; flow rates ensuring self-scouring of the entire system's piping must be properly calculated. Systems are designed on *branch layouts; loops are avoided*. Normal operating pressures in the range of 35 psig are employed for pressure sewer systems. With normal topsoil conditions, a light trencher digs a narrow trench deep enough to be below the frost line. Only two men are needed to lay the pipe and make the joints. Manholes and lift stations are unnecessary. Instead, simple valve boxes are provided for sectionalizing and access.

27. "Low Pressure Sewers Revisited," by R. Paul Farrell, Jr. Reprint from the Sep 1979 issue of the Journal of the New England Water Pollution Control Association.

It has been well documented that, if the collection system (*pressure* sewer) is confined purely to the domestic waste originating inside residences, per capita flows are in the order of 35 to 50 gal per capita per day (gpcd). Compared to the typical 100- to 125-gpcd design figure for conventional systems, it is obvious that great savings can be realized in both transport and treatment costs as a result of this dramatic reduction in volume. Given a situation in which pumping is required by topography, for example, a low pressure sewer system can usually be shown to have a lower operating cost (in both dollars and energy) because the smaller volume handled more than offsets the higher efficiency of the larger pumping stations. Design recommendations for pressure sewers currently in use call for a minimum velocity of 2 ft/sec This is consistent with older standards governing force main design.

Indoor installation of the grinder pump unit is recommended for ease in maintenance and protection from vandalism and weather. Concrete footings and anchors are nearly always required for outdoor units.

Mean Time Between Service Calls (MTBSC) for all grinder pump units for all causes has been estimated at 2.8 years (up to 1978).

Using the present worth method of economic analysis currently required by the Environmental Protection Agency (EPA), and depending upon the size of the project, interest rate, and whether or not overhauls are done onsite or at the factory, the author's calculations indicate an annual cost of between $35 and $60 per pump per year at 1978 prices. This will pay for power cost, minor repairs, major overhauls at 10-year intervals, and replacement at 20-year intervals.

28. "Milwaukee Study Area," by American Society of Civil Engineers. NTIS Report No. PB-186003, 1968.

This reference is part of an overall research study being conducted by the American Society of Civil Engineers (ASCE) to determine the feasibility of separating combined sewerage by using a system of pressure conduits to convey sanitary sewage from individual structures to an existing interceptor. Includes a detailed description of plumbing changes required to separate sanitary wastes from roof drains, and the work required to install a grinder-storage-pump unit in each building capable of discharging comminuted sewage to a pressure collection system located in the public right-of-way. A cost estimate of two alternative pressure sewer layouts has been made and compared to the cost of accomplishing in-house separation and area collection of wastes by the conventional gravity sewer system. (from BSWE)

29. "Non-Mechanical Considerations Involved in Implementing Pressurized Sewerage Systems," by D. H. Waller. *ASCE Combined Sewer Separation Project*, Tech. Mem. No. 12, May 1968.

The general concept on which the American Society of Civil Engineers (ASCE) Combined Sewer Separation Project was based involved the discharge of comminuted sewage from buildings, via relatively small pressure tubing, into new pressure sanitary sewers. Some of the nonmechanical questions involved with grinder pump units were:

1. "Who would purchase, install, own, service, and replace Project (grinder-pump) units?"
2. "Who would pay to operate them, i.e., who would pay for the power consumed by the units?"

Unusual noises or unusually prolonged operation indicated need for service of a grinder-pump unit; in some cases, overflowing sewage was the indicator for service.

30. "Onsite Systems: Farmers Home Administration," by C. W. Rose. *Individual Onsite Wastewater Systems*, Proceedings of the Fourth National Conference, National Sanitation Foundation, pp. 21-26, 1977.

Describes the Farmers Home Administration's involvement in planning waste treatment systems through financial aid to farmers, rural families, and communities. Also presents a view of the current status of onsite treatment, regional planning concepts, pressure sewer systems, and Ten State Standards, as they relate to Farmers Home Administration. (from BSWE)

31. "Plastic Pipe, Pressure Sewers, Mark Expansion," by T. C. Williams. *Water and Wastes Engineering*, Vol 12, No. 11, pp. 85-87, Nov 1975.

Innovative use of polyethylene pipe and installation of grinder pumps and pressure sewers marked the expansion that doubled the treatment capacity of the lagoon and irrigation system in Harbor Springs, Mich. This is the first known use of polyethylene pipe for a collection system and the first use of grinder pumps and pressure sewers in a collection system in the State of Michigan. To serve a resort area, flexibility of operation was necessary to cope with population fluctuations, and scenic qualities of the area had to be protected. The project eliminates discharge of septic tank and treatment plant effluent into several lakes and streams in the area. (from WRA)

32. "Pressure and Vacuum Sewer Demonstration Project - Bend, Oregon," by Jessie E. Eblen and Lloyd K. Clark. U. S. Environmental Protection Agency, Report No. EPA-600/2-78-166, Sep 1978.

A pressure sewer system collecting domestic septic tank effluent and a vacuum system collecting raw domestic sewage were constructed in the city of Bend, Oreg. The systems were operated and monitored for one year. Information presented for the project includes: construction costs, comparison costs, operation and maintenance, wastewater volumes, water use, energy consumption, and chemical characteristics. Table 19 of the study compares features of gravity, pressure, and vacuum sewer systems.

33. "The Pressure Sewer: A New Alternative to Gravity Sewers," by [illegible] Engineering, Vol 44, No. 5, pp. 50-53, 1974.

Use of grinder pumps to discharge household sewage into small diameter pressure [illegible] cost of installing treatment systems in a 12-home [illegible] Elimination of infiltration and inflow, [illegible] drainage, reduced sewage volume by two-thirds [illegible] (from WRSF)

34. "Pressure Sewer Demonstration," by I. A. Carcich, L. Hetling, and R. Farell. American Society of Civil Engineers, Journal of Environmental Engineering Division, pp. 25-40, Feb 1974.

A pressurized sewer system was extensively tested during a 13-1/4-month period in Albany, N. Y. Grinder pump units capable of macerating most wastewater solids to less than 1/4 in. in diameter were utilized. Nine of the original grinder pumps were exchanged for modified units. The modified units operated for 7-1/4 months and had five malfunctions (faulty pressure switch or time delay switch, loss of prime or grease clogging of pressure sensing tube, faulty or worn mechanical parts). The original grinder pump units had 39 similar malfunctions. The pressurized system was constructed using plastic pipes, 1-1/4 in. in diameter for the pressure sewer laterals and 1-1/4 to 3 in. for the pressure sewer main. The author states that the 3-in. pressure main was probably overdesigned and could have been 2 in. in diameter. A 2- to 5-ft/sec cleansing velocity is recommended to keep the mains free of grease. An analysis of the pressure gages data indicated the system was hydraulically loaded to near the maximum recommended working pressure of 35 psi. The theoretical total dynamic head computations for this system did not compare favorably with the actual recorded data. Where values of 5.3 and 11.6 psi were computed for the initial and final stages of the project, in actuality, pressures of 12 and 20 psi were recorded. The differential can be accounted for by the sizable reduction of the cross-sectional area of the pressure pipes by solidified grease. These pressure readings indicated that the grinder pump units will operate successfully at the high pressure rating as reported by the American Society of Civil Engineers research staff.

Because of elimination of infiltration, the average concentration of pollutants in the pressure sewer system was 100 percent greater than in conventional systems. Therefore, the difference in the strength of the pressure sewer wastewater must be taken into account in designing treatment facilities for the pressure system.

35. "Pressure Sewer Demonstration at the Borough of Phoenixville, Pennsylvania," by G. McKosh and D. Ramos. U. S. Environmental Protection Agency, Report No. EPA-R2-73-270, 1973.

A site in the Borough of Phoenixville, Pa., was selected for a pressure sewer demonstration. The project proved over a six-month period that a multiple residence pressure sewer system can adequately store peak loads of wastewater and grind and pump wastewater through small diameter plastic pipe to an existing conventional gravity sewer. Data collected and information are provided concerning the installation, operation, and maintenance of the system; its technical performance; problems encountered; and the characteristics of the wastewater as delivered to the existing gravity sewer. Appendix A of the paper includes operation and maintenance information and system start-up criteria for the grinder pump storage units.

36. "Pressure Sewer Design Procedure," by G. F. Hendricks and R. L. Sanson. Water and Sewage Works, Vol 120, No. 11 p. 53, 1973.

A design example for a pressure sewer system that pumps septic tank effluent only is presented. Fifty gallons per capita per day (gpcd) was assumed or 200 gal per household per day. Based upon the dimensions of an 800-gal septic tank, a 20-gal volume per inch of depth in the tank was estimated. One commercially available pumping unit can hold approximately 48 gal at a 36-in. depth. The pumping capacity of this unit ranged from 7 gpm at a total dynamic head (tdh) of 42 psi to 30 gpm at a tdh of 16 psi. An assumption was made that the average pump discharge pressure on the units would be 35 psi (80 ft of water) and the average pumping capacity would be 10 gpm. A water demand curve was developed for the area. From this curve it was determined that the peak water use for one user would be 15 gpm. Taking 10 gpm (average) ÷ 15 gpm (peak) equals 67 percent of the water demand. The author also could have assumed 40 percent simultaneous operation of the grinder pump units to determine flow in the pressure system. It was therefore determined to size the mains based upon a flow of 70 percent of the water demand curve.

37. "Pressure Sewer System Design," by L. J. Flanigan. Water and Sewage Works, pp. 25-87, Apr 30, 1979.

A review of the literature is presented on the methods of proper selection of values of parameters affecting the operation of a pressure sewer system and guidelines for the selection of pumps, piping, and other appurtenances utilized in the system. Design parameters include scouring velocity, the design flow rate, and frictional resistance (27 refs). (from EI)

38. "Pressure Sewer System Manual and Engineering Guide," Hydr-O-Matic Pumps, A Division of Wylain, Inc., Birmingham, Ala., 1978.

This manual and guide is for use in the design of pressure sewer systems employing Hydrogrind grinder pumps. The manual includes: pressure sewer application, system concept and design considerations, system design procedures, pumps and appurtenances, flowcharts, system layouts, diagrams of equipment, suggested design flow, pump selection, performance curves, and system specifications.

39. "Pressure Sewer Systems Gain New Popularity," Water and Sewage Works, pp. 84-87, Feb 1975.

The article discusses advantages and disadvantages of pressure sewer systems. System design considerations, cost comparison, and operation and maintenance are also discussed. A major advantage of a pressure sewer system is quick installation. A major disadvantage is that the pumping units are subject to mechanical failure. The author sees pressure sewers as a viable alternative to conventional sewer systems.

40. "Pressure Sewers," by W. C. Bowne. Prepared for Environmental

Research Information Center, U. S. Environmental Protection Agency, Cincinnati, Ohio, Jul 1979.

A thorough discussion of pressure sewer system basics is presented. Piping materials and pumps in current use are discussed. Pumps employed are: solids handling pump (SH), grinder pump (GP), and septic tank and effluent pump (STEP). A discussion of each pump is presented. Information on installation, damage prevention, maintenance and repair, air release valves, flows, cleansing velocity, electrical considerations, design features, septic tanks, operation and maintenance, and cost is presented. Also, information is given on semipositive displacement pumps and centrifugal pumps. Use of existing septic tanks is discussed (when using the septic tank and effluent pressure system). Easements, requirements of the engineer, and environmental aspects are included.

41. "Pressure Sewers," by I. G. Carcich. U. S. Environmental Protection Agency, Report No. EPA-670/2-73-077, pp. 65-87, Nov 1973.

The pressure sewer concept deals with a wastewater collection system that utilizes a newly developed grinder pump unit and small diameter plastic or metallic piping systems. Results of a 13-month study undertaken to evaluate the functional specifications of the pumping units and to gain operating experience on the mechanical performance, use pattern, operating cost, and maintenance requirements of said units are reported. A description of the grinder pump unit and the test results are given. Results indicated that plastic pipes and fittings functioned well for the duration of the demonstration project. The report recommends that pressure sewer systems be considered as available engineering technology for use where applicable (6 refs). (from WRA)

42. "Pressure Tubing Field Investigation," by L. S. Tucker. ASCE Report No. TM-5, NTIS PB-186011, 1967.

This technical memorandum covers that portion of Task 7 concerning tubing field-trial installations. Task 7 relates to special field-trial installations of tubing and conduits for the purpose of determining the nature and extent of practical difficulties that might be encountered in passing various tubing through a building sewer, in suspending or otherwise attaching a pressure conduit in the street sewer, and in making tubing-to-conduit connections. (from BSWF)

43. "Pressurized Air Simplifies Conveying Sewage Solids," by C. T. Blanchard. Water and Sewage Works, Vol 123, No. 11, pp. 78-79, 1976.

A discussion of the CPC Pneumatic Ejector System is presented. The ejection system can be utilized to pneumatically convey grit, screenings, and sludge safely, in totally enclosed pipelines, in any direction. A complete description with diagrams on how the pneumatic ejectors operate is included.

44. "Pressurized Sewer Collection Systems," by J. Leckman. PB-216 166, Illinois Institute for Environmental Quality, Chicago, Contract Report, Nov 1972.

The grinder pump/pressurized collection systems have different characteristics than a conventional gravity sewage system. For example, the wastewater is stored at the home site and then discharged at a uniform rate at some future time not necessarily related to consumptions of the water; consequently, sewage discharge is not as directly related to water consumption as it is in a gravity sewage collection system. Also, being in a pressurized system, infiltration is not encountered; therefore, the total volume of water delivered to a sewage treatment plant is considerably less. The commercial grinder pump package unit generally consists of a grinder, pump, shut-off valve, check valve, electrical controls, fiberglass or steel housing, and accessories to make the unit completely operable with only the electrical power connections and sewer inlet-outlet connections required for field installations. The cost for the package unit with installation is between $1000 and $1500, depending on the manufacturer selected and whether an indoor or outdoor location is used. Monthly operational cost of a pump grinder unit is minimal and consists primarily of the cost of electricity (11 refs). (from WRA)

45. "Pressurized Sewer Systems: Regulatory Agency's Viewpoint," by David M. Cochran. Presented at the Water Pollution Control Federation Conference, Denver, Colo., Oct 1974.

Criteria needed to consider alternate technologies in Texas are discussed in this paper. The regulatory agency or reviewer looks for sound engineering judgment when reviewing proposals for sewer systems. For example, is the terrain in a proposed sewer system area so rocky or undulating that the cost of a gravity sewer would be prohibitive? In that case, a pressure sewer system or others should be considered. Levels of approvals for projects are discussed. Unconditional approvals are bestowed upon time-tested methods generally accepted throughout the wastewater field. Conditional approvals are usually reserved for designs that deviate from the normal practice. The regulatory agency looks for sound engineering judgment or economic justification when reviewing designs that deviate from standard criteria.

46. "Pressurized Waste Water Collection," by E. J. Bowles. Presented at the Water Pollution Control Federation Conference, Atlanta, Ga., 1972.

This 1972 paper discusses the history and character of wastewater collection. It is stated that the major cost of any waste disposal system is related, not to treatment, but to collection. The paper also discusses the basics of pressure sewer systems and some systems that had been installed in Texas.

47. "Protecting Water Supplies Through Sewerless Sanitation," by H. H. Leich. Ekistics, Vol 43, No. 254, pp. 22-27, 1977.

Conventional sewage disposal has created numerous problems. Aerobic tanks, biological tanks, composting toilets, incinerating toilets, oil flushed toilets, and pressure or vacuum toilets are described as alternatives to conventional sewer systems. (from BSWF)

48. "Relationship of Sewage Characteristics to Carrying Velocity for Pressure Sewers," by M. Floyd Hobbs. PB-185 991, ASCE Combined Sewer Separation Project, FMC Corp. Report No. R-2598, Aug 1967.

Minimum carrying velocities for solid phase wastewater in smooth plastic 2, 3, 4, 6 in., etc., pressure pipes were measured using comminuted and uncomminuted raw sewage. The minimum velocity for scouring and the maximum velocity for depositing were essentially the same. Velocities appeared to be independent of: the concentration magnitudes of suspended solids, the sand concentration, and the size distribution of suspended matter and sand for the sewage studied. (from WRA)

49. "Report on the Performance of Grinder Pump Model Farrell 210," Report No. C-9-3, National Sanitation Foundation Testing Laboratory, Ann Arbor, Mich., Sep 1973.

Performance report of grinder pump includes: basic criteria, charts, diagrams, evaluation, raw waste characteristics, characteristic curves (total dynamic head), test data, specifications, and design data. Some conclusions were: materials were durable and structurally sound; component parts (subject to malfunction or wear) were accessible; and no structural weaknesses were detected. The Grinder Pump Model Farrell 210 is capable of performing its design function under expected conditions of application.

50. "Rural Wastes: Ideas Needed," by C. W. Rose. Water and Wastes Engineering, Vol 9, No. 2, pp. 46-47, 1972.

The need for alternative collection and disposal systems for rural areas is discussed. Pressurized, small diameter mains, and solids size reduction are seen as viable solutions toward obtaining a low-cost, dependable system for rural waste management. (from BSWF)

51. "Selecting Sewerage Systems to Fit Site Conditions and Budget," by David E. Johnson. National Association of Home Builders, Washington, D. C., Civil Engineering-ASCE, Vol 48, No. 9, p. 90, Sep 1978.

Several alternative sewer systems have been developed in response to needs in rural and poor communities. Pressure sewer systems, vacuum sewer systems, individual home aerobic units, mound systems, and evapotranspiration systems are discussed and diagrammed. The need and incidence of sewer moratoriums are examined, and the effects on housing are described. (from EI)

52. "State Park Gets Good Treatment," by F. A. Jay and J. L. Kroesche. Water and Wastes Engineering, Vol 13, No. 11, pp. 65-66, 71, 1976.

Pressurized collection networks with variable capacity extended-aeration tanks and an effluent irrigation system were used to combat problems engendered by topography, soil, and effluent quality limits at Inks Lake State Park, Tex. Seasonal flow variations of 3,000 to 70,000 gal/day dictated the use of a flexible extended-aeration plant. The selection of the design criteria is discussed. (from BSWF)

53. "Status of Pressure Sewer Technology," by James F. Kriessl. U. S. Environmental Protection Agency, Cincinnati, Ohio. EPA Technology Transfer Report, Mar 7, 1977.

Pressure sewer systems are a viable alternative technology and should be considered in any cost-effective analysis of alternative wastewater management systems in rural communities. Pressure sewers offer many advantages in areas where population density is low, severe rock conditions exist, high groundwater or unstable soils prevail, or undulating terrain predominates. The most serious impediment to wider pressure sewer technology adoption is the lack of comprehensive long-term operation and maintenance data and treatment information. The two types of pressure sewer system designs, grinder pump systems and septic tank effluent pumping systems, are detailed (55 ref, 3 diagrams, 13 drawings, 13 graphs, 1 map, 7 tables). A simplified design example is also included. (from NTIS)

Vacuum systems

1. "Alternatives for Small Wastewater Treatment Systems: Pressure Sewers/Vacuums Sewers," by J. Kriessl, I. A. Cooper, and J. W. Rezek. U. S. Environmental Protection Agency Technology Transfer Seminar, Report No. EPA-625/4-77-011. Oct 1977.

The U. S. Environmental Protection Agency Technology Transfer Report includes background information, descriptions, case studies, construction considerations, costs, and information on operation and maintenance of pressure and vacuum sewers. A design example for a vacuum system is presented in Appendix B. Lower capital costs and significantly shorter construction times are inherent in pressure sewer systems, as compared to conventional methods. But, pressure sewers should only be considered with properly conceived management arrangements (i.e. maintenance of grinder pump units).

Vacuum sewer systems offer lower construction costs, decreased infiltration/inflow, reduced water consumption with use of vacuum toilets, and ease of installation. But, the complexity of vacuum equipment requires operating personnel to be properly trained to maintain a vacuum sewer system. Procedures to follow in the event of a breakdown in a vacuum system are also included in the report.

2. "Characteristics of Vacuum Wastewater Transfer Systems," by E. P. Skillman. Presented at the American Society of Mechanical Engineers, Publication 76-ENAs-43, New York, N. Y., Apr 1977.

An experimental vacuum wastewater collection/transport system was built and tested at Naval Air Station, Point Mugu, Calif. The paper describes the characteristics of a vacuum system. The small system tested included a 1000-gal tank for shower, laundry, etc.; three vacuum toilets; three mini-flush gravity toilets discharging into a 55-gal gravity interface tank; and three independent transport mains 1100 ft long. The vacuum transport mains were installed aboveground and considerable cost savings resulted. The tests carried out indicated that high air to water ratios produced a measurable drop in transport efficiency.

3. "Cost-Effectiveness of On-Site and Community Sewerage Alternatives," by J. J. Troyan et al. Civil Engineering, Vol 47, No. 12, pp. 84-89, 1977.

Outlines a procedure for assessing the cost-effectiveness of wastewater treatment alternatives. Advantages, disadvantages, limitations, and cost factors for evaluating conventional gravity sewers, small diameter gravity sewers, pressure sewers, and vacuum sewers are described. (from BSWF)

4. "Demonstrating the Feasibility of Vacuum and Pressure Sewers," by L. K. Clark and J. E. Eblen. Public Works, Vol 108, No. 4, pp. 81-84, Apr 1977.

Vacuum and pressure systems were utilized in a collection system constructed in Bend, Oreg. Specific information about the pumps used and the type and amount of excavation is presented. Depth of burial for pressure and vacuum systems is governed only by frost depth or surface loading conditions. The author gives a cost of the vacuum system as $9.75/ft. This figure is nearly twice the $5/lin ft for pressure sewers. The author mentions that "relays to signal the operation of the individual vacuum release valves have not performed satisfactorily to date and must be changed." Also, the draining of the condensate from the vacuum pumps had taken more operator time than any other item, about half an hour daily, but changes were being effected. Operator time was largely devoted to adjusting the sensor system for the vacuum valve operation and getting the signal system to report events to the vacuum station. The author offers no operation and maintenance information on pressure sewers.

5. "Envir-O-Pak: Water and Wastewater Equipment, Sales and Design Manual," Willow Grove, Pa.

Includes figures, charts, drawings, and specifications. Recycle and vacuum collection systems, pressure sewer systems, etc., are discussed. Innovative alternative systems are stressed. Basic wastewater data supplied.

6. "Matthews, Virginia (O&M Costs)," Case Studies, AIRVAC, Rochester, Ind.

A vacuum sewer system was installed in Matthews, Va., in 1975. The groundwater table is high in Matthews. During construction of the system, controllers and sensors were inadvertently flooded. All valve pits had to be modified to breathe above the maximum anticipated flood level to eliminate this problem. On one occasion a solenoid valve malfunctioned and the sewage was drawn by one vacuum station a length of 6250 ft. Bids for a conventional gravity system and vacuum system were $650,000 and $350,000, respectively. During 1975, 1976, and 1977, data were collected on the cost of power for the vacuum stations. Vacuum station power costs ranged from $38.60/month to $178.20/month. Vacuum station power costs per day ranged from $1.15 to $3.08. No maintenance costs were supplied. No infiltration occurs with vacuum systems, and Matthews averaged a flow of 30,000 gal/day. The author states that one full-time employee can handle the entire system.

7. "Pressure and Vacuum Sewer Demonstration Project - Bend, Oregon," by Jessie E. Eblen and Lloyd K. Clark. U. S. Environmental Protection Agency, Report No. EPA-600/2-78-166, Sep 1978.

A pressure sewer system collecting domestic septic tank effluent and a vacuum system collecting raw domestic sewage were constructed in the city of Bend, Oreg. The systems were operated and monitored for one year. Information presented for the project includes: construction costs, comparison costs, operation and maintenance, wastewater volumes, water use, energy consumption, and chemical characteristics. Table 19 of the study shows results of gravity, pressure, and vacuum sewer systems.

8. "Protecting Water Supplies Through Sewerless Sanitation," by H. H. Leich. Ekistics, Vol 43, No. 254, pp. 22-27, 1977.

Conventional sewage disposal has created numerous problems. Aerobic tanks, biological tanks, composting toilets, incinerating toilets, oil flushed toilets, and pressure or vacuum toilets are described as alternatives to conventional sewer systems. (from BSWF)

9. "Selecting Sewerage Systems to Fit Site Conditions and Budget," by David E. Johnson. National Association of Home Builders, Washington, D. C., Civil Engineering-ASCE, Vol 48, No. 9, p. 90, Sep 1978.

Several alternative sewer systems have been developed in response to needs in rural and poor communities. Pressure sewer systems, vacuum sewer systems, individual home aerobic units, mound systems, and evapotranspiration systems are discussed and diagrammed. The need and incidence of sewer moratoriums are examined, and the effects on housing are described. (from EI)

10. "System for Transporting Wastewater by Vacuum," by M. A. Boogay and V. I. Crawford. NTIS Report No. AD-D004 3771 8ST, 1977.

An apparatus is provided for re-forming wastewater slugs in a vacuum transport disposal system. The apparatus comprises a container interposed into the wastewater transport tube of the disposal system and having a single inlet and two outlets. (from BSWF)

11. "System Study, Vacuum Sewage Collection," Hittman Associates, Inc., Columbia, Md., NTIS Report No. AD-744 339, Final Report No. HIT-510, Dec 1971.

Gravity sewer systems and vacuum sewer systems for use in Navy advance bases were compared for effectiveness and cost. A vacuum system using low flush water toilets and vacuum transport of the combined wastes was selected for evaluation. The effectiveness of both gravity and vacuum sewer systems was evaluated on the basis of (a) system reliability,

(b) operational requirements, (c) maintenance requirements, (d) installation requirements, (e) ease of repair, (f) terrain conditions, (g) susceptibility to attack, (h) size and weight, and (i) space requirements. Cost estimates were also prepared for both systems. It was concluded that vacuum sewer systems offered improved design flexibility under adverse site and construction conditions. (from WRA)

12. "Vacuum Sewer Systems and Their Possible Canadian Applications," by D. W. Averill and G. W. Heinke. Canadian Journal of Civil Engineering, Vol 1, No. 1, pp. 50-61, Sep 1974.

The basic principles of vacuum sewer systems are reviewed and their introduction to Canada is described. A vacuum sewer uses air pressure instead of gravity as the driving force for wastewater transport. Wastewater is moved in plugs separated by air gaps at high velocities through small diameter pipes. The pressure differential of about one-half atmosphere is created by a central vacuum pump. Specially designed vacuum toilets, valves, and a central collection tank complete the system. Discussed are vacuum transport theory and design practices, including flow theory and friction loss by a homogeneous model. The advantages of a vacuum sewer system over a conventional gravity system are its ability to transport wastewater horizontally and to a certain extent upgrade, its much lower water usage, and its lower capital cost. However, the length capacity and lift potential of vacuum sewers are limited by the available pressure differential, which precludes their use in many cases. There appears to be considerable potential for their application in Canada, particularly in remote locations such as cottage areas and in the Arctic. (from WRA)

13. "Vacuum Sewage Transport and Collection," by G. P. Janicek and M. E. Simpson. Pollution Engineering, Vol 5, No. 9, pp. 76-79, 1973.

The physical and economic requirements of vacuum sewage collection systems and some of their component design details are discussed. Construction, maintenance, operation costs, and personnel requirements of pressure/vacuum systems are compared to traditional sewer systems. (from BSWF)

14. "Vacuum Sewerage System Design Manual," by AIRVAC. Rochester, Ind., 1978. Also Design Drawings.

Included in the Vacuum Sewage System Design Manual: (1) general description and history of vacuum sewage; (2) general features of the AIRVAC System; (3) technical design data with design example; (4) applications to marinas; (5) cost-effective applications; (6) system operation and maintenance; (7) friction loss charts for PVC charts; (8) installation; (9) training; (10) equipment specifications and services available; (11) AIRVAC demonstration facility and valve warranty; and (12) figures, diagrams, and charts.

Lift stations

1. "Analysis of Economic Sewage Lift Station Design," by O. Smolik. Water and Sewage Works, Ref. Issue, pp. 58-62, Apr 1977.

A procedure for the economical design of a sewage lift station was presented. The objective was to determine a standard type or size of station and a standard control for specific magnitudes of inflow. Design probiems included wet well size and the capacity and number of pumps for a given sewage inflow. Equations were included which could aid the determination of relationships between well size, pump efficiency, and sewage inflow. Other equations were designed to specify inflow at a station with no flowmeter. Use of these steps was expected to reduce costs at the design stage and to increase efficiency of the system. (from WRA)

2. "Considerations for Electrical Design in Sewage Lift Stations," by L. M. Applegate. Public Works, Vol 107, No. 12, pp. 59-60, Dec 1976.

The article discusses sewage lift stations built by Oroville (California) Sewage Commission. These stations utilize variable frequency drive pumps to solve the problem of on-off operation of pumps.

3. "Design Proposals for Submersible Sewage Lift Stations," by H. G. Kelly. Water and Sewage Works, Ref. Issue, pp. 76-90, Apr 1977.

Designs are presented for submersible sewage lift stations. Design factors considered were construction materials, sizing, pump types, power and controls, hydraulic conditions, operation and maintenance needs, and costs. Practical design can be achieved for flows less than 1500 gpm. Centrifugal pumps are generally used, but progressive cavity pumps and pneumatic ejectors have been used in low flow-high head applications. Concrete, fiberglass, or a protected metal are the usual construction materials, depending upon specific site, design, and construction considerations. A friction loss equation should be derived before the selection of system components, and the system head curve should reflect its optimum solution. System hardware should be selected for ease of installation, operation, maintenance, cleaning, and repair. Numerous figures and graphs are included. Costs for grinder pumps and lift stations are presented. Operation and maintenance costs in 1975 dollars are also included (18 refs). (from WRA)

4. "Lift Station Designed to Use Old and New Concepts," by R. E. Wallace. Public Works, pp. 88-90, Sep 1974.

The author discusses lift station design and maintenance. Desirable features of lift stations are reliability and ease of installation. The author states that during most of the last decade lift station repairs consisted of refurbishing the old vertical mounted flexible shaft pump and motor stations to new design capacities and installing new small stations with close-coupled pumps and motors in outlying areas. The most satisfactory station for installation in outlying areas has been the factory-built, underground dry pit station using close-coupled pumps and motors with positive suction head. For flows less than 100 gpm, pneumatic ejectors have given good service. The factory-built and factory-tested stations seem to eliminate at least 75 percent of the construction problems that, when improperly solved, become operational problems. With small factory-built stations, 50 to 500 gpm, and the availability of replacement parts, the author has not been overly concerned with station flooding due to an internal break.

5. "Operating Small Water and Sewer Systems," by Warren H. Milliard. Water and Sewage Works, pp. 60-63, Feb 1975.

The authors stress the importance of routine maintenance, checklists, and record keeping. A checklist for lift stations is included, along with the recommendation that lift stations be inspected every other day. Emergency plans should be provided in the event of equipment or system failure.

6. "Submersible Lift Stations Cut Pump Maintenance Costs," Water and Sewage Works, Vol 122, No. 8, pp. 64-65, Aug 1975.

Problems with shaft-driven pumps and pneumatic ejector type pumps in Foster City, Calif., led to replacement with submersible type lift stations. Saltwater, dampness, and sand caused failures of the shaft-driven and pneumatic ejector pumps. Twenty-four of the lift stations have been equipped with submersible pumps (out of 34). Total expenditures for Foster City for parts during 1971-1975 totalled only $933. All personnel involved with the lift stations have attended technical clinics and are able to dismantle and reassemble submersible pumps proficiently. As part of a semiannual inspection-maintenance program, pumps are washed, then sandblasted to bare metal. After inspection and repair, exterior surfaces are coated with bitumastic epoxy to protect metal surfaces against corrosive wastewater. A 125-kw, trailer-mounted generator unit (capable of operating any lift station in the system) is available to handle power failure problems in an emergency. If many stations are involved in a power failure, the emergency generator is moved from station to station (starting with the largest) until power has been restored.

General

1. "Better Water Resources Through Sewerless Sanitation," by H. H. Leich. Water Resources Bulletin, Vol 13, No. 2, pp. 401-407, 1977.

General discussion of alternative, onsite waste disposal systems now available or under development. Aerobic treatment units, recycling, composting, incinerating, and closed-loop toilets, as well as pressure systems, are briefly decribed. (from BSWF)

2. "Collection Systems," Public Works Manual and Catalog File, Public Works Journal Corp., Ridgewood, N. J., pp. D.2-D.8, 1977.

The article discusses the piping system used to transport wastewater. Manufacturer's specifications, testing, installation, and lining materials are presented for various pipes. Pumps, gates, valves, lift stations, etc., are also discussed. Types of thermoplastic pipe employed for sewer systems are PVC (polyvinyl chloride), ABS (acrylonitrile butadiene-styrene), PE (polyethylene), and SR (styrene rubber). Manufacturers are listed in Section C-5.5 of the paper.

3. "Cost to the Consumer for Collection and Treatment of Wastewater," by Robert Smith and Richard G. Eilers. Project No. 17090, Jul 1970. Available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. EPA Report No. 17090-07/70, 1970.

This 1970 U. S. Environmental Protection Agency report presents national averages per capita cost for collection and treatment of municipal wastewater. The status of collection and treatment in the United States is discussed and estimates are made of needed additional expenditures. Cost relationships for construction and operating and maintenance are presented. Sewer maintenance cost data are also presented. Of the cities surveyed, an average value for operation and maintenance of sewers for the years 1967-1968 was 30.8¢/ft.

4. "Cost-Effectiveness of Alternative Sewage Collection Treatment and Disposal Systems at Recreational Areas," by Mesbah V. Ahmed, Arun G. Walvekar, and Kenneth B. Young. Published by Institute of Electrical and Electronic Engineers (Cat n 78CH1415-9), New York, N.Y., Vol 2, pp. 439-449, 1978.

This paper develops a model that selects the least costly combination of collection, treatment, and disposal of wastewater at recreational areas (a systems approach).

5. "Cost-Effectiveness of On-Site and Community Sewerage Alternatives," by J. J. Troyan et al. Civil Engineering, Vol 47, No. 12, pp. 84-89, 1977.

Outlines a procedure for assessing the cost-effectiveness of wastewater treatment alternatives. Advantages, disadvantages, limitations, and cost factors for evaluating conventional gravity sewers, small diameter gravity sewers, pressure sewers, and vacuum sewers are described. (from BSWF)

6. "Cost-Minded Community Chooses Small Diameter Gravity System," by Robert T. Fey and Carl C. Crane. Water and Sewage Works, pp. 58-61, Jun 1978.

The town of Westboro, Wisc., installed a small diameter gravity system in their community in 1977. The system contained individual septic tanks. All of the liquid effluent from the tanks was conveyed via small diameter (1-1/2- to 3-in.) PVC pipes to an absorption field. The PVC pipe was ensured a tight fit by the use of O-rings and a solvent joint. During heavy rains in September 1977 no fluctuation in normal flow was observed. Immediately before the absorption field siphoning chambers are used, they are allowed to fill with effluent. Discharge takes place when approximately 9500 gal is present. During the winter, the absorption field can be drained to prevent freezing. The author reports that the system is operating up to their expectations.

7. "Evaluation of Wastewater Treatment Alternatives for Small Communities," National Utility Contractors Association, 815 15th Street, N.W., #838, Washington, D.C., 1979.

Process descriptions, advantages, disadvantages, restrictions on the process, performance, reliability, and cost analyses for each system are discussed in detail. Conventional gravity sewer systems, when followed by wastewater treatment ponds or package plants, were found to be cost-effective over the onsite alternatives applicable to small communities. Capital costs for the systems were similar, but operation and maintenance costs were much higher for alternative systems. (from BSWF)

8. "Insuring Trouble-Free Pump Operation," by Arnold LaFarge. Water and Sewage Works, p. 603, May 1978.

Trouble-free pump operation combines proper design, correct application, correct handling of equipment on the job site prior to installation, installation as specified, and maintenance according to manufacturer's directions. A pump should be situated on a firm foundation. A pump which has been "flooded out" must be dismantled, the bearings cleaned, and inspected and repacked with grease. A gate valve installed after a check valve can be used to isolate a pump for maintenance, priming, starting, and stopping. Keep a maintenance record. Allow for downtime of the pump. The author includes figures and discussions of setting pumps up, alignments, pump design, and piping joints.

9. "Least Cost Method for Sewer Design," by Stephen Walsh and Linfield C. Brown. Journal of the Environmental Engineering Division, pp. 333-345. Jun 1973.

The paper presents a computerized method of sewer design. Algorithms and subroutines used are discussed. An example is given.

10. "Onsite Systems: Farmers Home Administration," by C. W. Rose. Individual Onsite Wastewater Systems, Proceedings of the Fourth National Conference, National Sanitation Foundation, pp. 21-26, 1977.

Describes the Farmers Home Administration's involvement in planning waste treatment systems through financial aid to farmers, rural families, and communities. Also presents a view of the current status of onsite treatment, regional planning concepts, pressure sewer systems, and Ten State Standards, as they relate to Farmers Home Administration. (from BSWF)

11. "Operating Small Water and Sewer Systems," by Warren H. Milliard. Water and Sewage Works, pp. 60-63, Feb 1975.

The authors stress the importance of routine maintenance, checklists, and record keeping. A checklist for lift stations is included, along with the recommendation that lift stations be inspected every other day. Emergency plans should be provided in the event of equipment or system failure.

12. "Protecting Water Supplies Through Sewerless Sanitation," by H. H. Leich. Ekistics, Vol 43, No. 254, pp. 22-27, 1977.

Conventional sewage disposal has created numerous problems. Aerobic tanks, biological tanks, composting toilets, incinerating toilets, oil flushed toilets, and pressure or vacuum toilets are described as alternatives to conventional sewer systems. (from BSWF)

13. "A Study of Highway Rest Area Wastewater Disposal," Public Works, pp. 70-74, Dec 1972.

Problems, design criteria, and recommendations for handling wastewater flows from rest areas in Washington State are presented. Peak flows are developed from traffic data and water use data. Washington State has experienced trouble with septic tank systems, such as: (1) inadequate septic tank capacity for loads experienced; (2) drain field failures due to poor soil porosity, heavy equipment passing over, high groundwater table; (3) sticking flushometer valves due to sand grains that may cause the septic tank to drain into the absorption field and clog it; (4) pump motor failures; (5) clogging of septic tank with paper; (6) vandalism, etc. Recycled toilet systems are recommended in certain areas of Washington State.

14. "U. S. EPA Response to PL 92-500 Relating to Rural Waste Water Problems," by J. F. Kriessl. Individual Onsite Wastewater Systems, Proceedings of the Third National Conference, National Sanitation Foundation, pp. 21-36, 1976.

Presents the response of U. S. Environmental Protection Agency Office of Research and Development to the mandates of Sections 104 and 105 of PL 92-500. Topics include advanced collection technology, onsite alternative systems, septic tank sludge handling, and cost estimates of onsite alternatives. (from BSWF)

15. "Wastewater Collection," by Samar Chatterjee et al. Sewer System Evaluations, Chicago, Water Pollution Control Federation Journal, Vol 50, No. 6, p. 1139, Jun 1978.

Wastewater collection literature is reviewed. Wastewater project planning is surveyed. System construction, sewer system evaluation, maintenance, rehabilitation, overflow prevention, and wastewater pumping are considered (111 ref). (from EI)

16. "Wastewater Collection System Criteria, Part II," by Michael G. Hoover. Water and Sewage Works, pp. 70-72, Apr 1975.

Hydraulics, construction, and system economics of wastewater collection systems are discussed. Accurate flow estimates must be obtained in order to design the collection system and treatment plant. Economic analysis can be performed with confidence on accurate flow measurements. Additional amounts of money spent initially to reduce extraneous flows could produce savings in the long run. An example is included. Materials (such as concrete and ductile iron pipe) and their handling in the field are also discussed.

Recycle systems

1. "Better Water Resources Through Sewerless Sanitation," by H. H. Leich. Water Resources Bulletin, Vol 13, No. 2, pp. 401-407, 1977.

General discussion of alternative, onsite waste disposal systems now available or under development. Aerobic treatment units, recycling, composting, incinerating, and closed-loop toilets, as well as pressure systems, are briefly decribed. (from BSWF)

2. "Envir-O-Pak: Water and Wastewater Equipment, Sales and Design Manual," Willow Grove, Pa.

Includes figures, charts, drawings, and specifications. Recycle and vacuum collection systems, pressure sewer systems, etc., are discussed. Innovative alternative systems are stressed. Basic wastewater data supplied.

3. "A Recycled-Water Sanitary Waste Disposal System," by W. J. Shoupp. PB-291 740. Ph.D. Dissertation. West Virginia University, Morgantown, 1978.

A closed, recycled water-sanitary waste disposal system for laboratory study was developed. The system was based on a 1000-litre capacity, water-filled biodegradation tank. Data response curves were created during the long-term (about 130 days) experimental runs. (from WRA)

4. "Water Reuse at Highway Rest Areas: Evaluation Phase," by C. E. Parker, Virginia Highway and Transportation Research Council, Report No. VHTRC 78-R22, PB-278 542, Dec 1977.

A system for recycling water used to flush water closets at a highway rest area on I-81 at Fairfield, Va., is evaluated. The method produces water of acceptable standards with no objectional odor or color, no foaming or apparent suspended solids, and low bacterial count. Preliminary bench-scale research indicated that extended aeration biological treatment followed by granular media filtration would be acceptable. This led to installation of a full-scale field system at an existing rest area. A closed-loop system was set up to and from water closets, with water balance achieved by wasting an amount of recycled water equal to the water input from sewered potable water. Recycling was estimated at 95 percent. Operation of the closed-loop extended aeration and granular filter system was similar to conventional operation of these processes. The influence of nitrogen accounted for the most significant operating difference. Ammonia nitrogen transformation to nitrite and nitrate nitrogen resulted in an operating pH of 5.5 to 6.0 and, as a result, incomplete nitrification occurred. Although nitrogen buildup in the form of ammonia, nitrite, and nitrate did occur, the concentrations did not cause a reduction in organic biological oxidation efficiency. Quality of the water varied between winter and summer operation, but remained acceptable as a flush fluid. (from WRA)

5. "Waterless Sanitation for Rest Areas," by R. W. Fullerton, Chrysler Corp. Water and Sewage Works, Vol 121, No. 6, pp. 86-88, Jun 1974.

A waterless sanitation system is described. This closed-loop no-discharge nonbiological sewage disposal system uses mineral oil instead of water as the flush fluid to transport human waste. The flushing fluid carries waste from conventional commodes to a separation tank where the sewage is separated by gravity. The fluid is filtered, purified, and reused indefinitely. Disposal is by burning in a pollution-free incinerator. Ash should be removed from the incinerator weekly.

Other References

1. "Combined Sewer Separation Using Pressure Sewers," American Society of Civil Engineers, U. S. Dept. of the Interior, Federal Water Pollution Control Administration, Report No. ORD-4, 1969.

2. "Design Criteria for Vacuum Wastewater Transfer Systems in Advanced Base Applications," by E. P. Skillman. Technical Note No. N-1554, Construction Engineering Laboratory, Port Hueneme, Calif., Naval Facilities Engineering Command, May 1979.

3. "Design of Small Systems Wastewater Treatment Facilities, Part 2 of 3," by U. S. Army Engineer Waterways Experiment Station, CE, EM 1110-2-501, Apr 1980.

4. "Handbook of PVC Pipe Design and Construction," by Uni-Bell Plastic Pipe Association. Dallas, Tex., ca. 1977.

5. "Integrated Utility Systems - For Remote Alaskan Villages," by B. H. Reed et al. International Symposium on Wastewater Treatment in Cold Climates, Environment Canada Economic and Technical Review Report EPS 3-WP-74-3, pp. 549-569, 1974.

6. "Manual for Onsite Wastewater Treatment & Disposal Systems," Draft, by Curtis J. Schmidt et al. U. S. Environment Protection Agency Report, Contract No. 68-01-4904, Project Officers: Robert M. Southworth, Robert P. G. Bowker, 401 M. St. S.W., Washington, D. C. Sep 1979.

7. "Minimum Transport Velocity for Pressurized Sanitary Sewers," by Murray B. McPherson et al. ASCE Combined Sewer Separation Project, Tech. Mem. No. 7, PB-186 013, Nov 16, 1967.

8. "New Types of Wastewater Collection for Small Communities," by James F. Kriessl. U. S. Environmental Protection Agency, presented at Central New York Regional Planning and Development Board Wastewater Treatment Systems for Private Homes and Small Communities Conference, 1978.

9. "A New Vacuum Sewage System by IFO Wartsila," Shipbuilding and Marine Engineering International, Vol 99, No. 1204, pp. 684-686, Dec 1976.

10. "Recommended Standards for Sewage Works," by Great Lake - Upper Mississippi River Board of State Sanitary Engineers. Health Education Service, Albany, N. Y., 1971.

11. "A Simple Portable Vacuum Pump," by R. D. King. Journal of the Limnological Society of Southern Africa, Vol 2, No. 2, p. 63, 1976.

12. "Six Months Experience with a Pressure Sewer System Demonstration," by Italo Carcich et al. N.Y. State Dept. of Environmental Conservation. Tech. Paper No. 4, Apr 1971.

13. "Wastewater Engineering," by Metcalf & Eddy, Inc. McGraw-Hill, N.Y., 1972.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Kelsi, Frances M

Selected references on innovative/alternative wastewater collection systems for Corps of Engineers recreation areas / by Frances M. Kelsi, M. John Cullinane, Jr. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1981.

45 p. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; EL-81-2)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C.

References: p. 8-45.

1. Recreation. 2. Recreation facilities. 3. Waste water disposal. I. Cullinane, M. John, joint author. II. United States. Army. Corps of Engineers. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; EL-81-2.

TA7.W34m no.EL-81-2